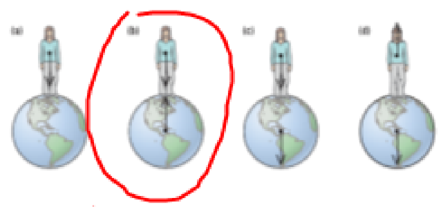
Universal Gravitation

1) What factors affect the weight of an astronaut during a rocket flight? How does the astronaut's weight change?

- distance from centre of Earth
- "apparent weight" would change with acceleration

2) Which diagram best represents the gravitational force acting on you and on Earth? Explain your reasoning.



- each object feels a gravitational force towards the centre of mass of the other object

3) How could you distinguish between a 5.0-kg medicine ball and a basketball in outer space without looking at both objects?

- move them with your hands
- one with more inertia will require more force to accelerate

4) Two people, A and B, are sitting on a bench 0.60 m apart. Person A has a mass of 55 kg and person B a mass of 80 kg. Calculate the magnitude of the gravitational force exerted by B on A. (8.2×10^{-7} N)

$m_A = 55 kg$

$m_B = 80 kg$

$\vec{F}_g = ?$

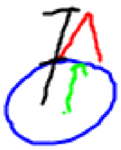
$d = 0.60 m$

$$\vec{F}_g = \frac{G m_A m_B}{d^2}$$

$$F_g = \frac{6.67\times10^{-11}\ Nm^2/kg^2\,(55kg)(80kg)}{(0.60m)^2}$$

$$\boxed{F_g \approx 8.2\times10^{-7} N}$$

5) Mount Logan in the Yukon is 5959 m above sea level, and is the highest peak in Canada. Earth's mass is 5.97 x 10^{24} kg and Earth's equatorial radius is 6.38 x 10^6 m. What would be the difference in the magnitude of the weight of a 55.0-kg person at the top of the mountain as compared to at its base. Assume that Earth's equatorial radius is equal to the distance from Earth's centre to sea level. (1.00N)



$m_E = 5.97\times10^{24}\,kg$
$m_p = 55.0\,kg$
$d_1 = 6.38\times10^6\,m$
$d_2 = 6.38\times10^6\,m + 5959\,m$
$= 6385959\,m$

① At Surface

$F_g = \dfrac{G m_E m_p}{(d_1)^2}$

$F_{g_1} = \dfrac{6.67\times10^{-11}(5.97\times10^{24})(55.0)}{(6.38\times10^6)^2}$

$F_{g_1} = 538\,N$

② On Mountain

$F_{g_2} = \dfrac{6.67\times10^{-11}(5.97\times10^{24})(55.0)}{(6385959)^2}$

$F_{g_2} \simeq 537\,N$

③ Difference

$F_{g_1} - F_{g_2} = \boxed{1N}$

6) The mass of the *Titanic* was 4.6 x 10^7 kg. Suppose the magnitude of the gravitational force exerted by the *Titanic* on the fatal iceberg was 61 N when the separation distance was 100 m. What was the mass of the iceberg? (2.0 x 10^8 kg)

$M_T = 4.6\times10^7\,kg$
$\vec{F}_g = 61N$
$d = 100\,m$
$M_I = ?$

$\vec{F}_g = \dfrac{G M_T M_I}{d^2}$

$\dfrac{F_g d^2}{G M_T} = M_I$

$M_I = \dfrac{61N(100m)^2}{(6.67\times10^{-11}N\,m^2/kg^2)(4.6\times10^7\,kg)}$

$\boxed{M_I \simeq 2.0^8\,kg}$

$M_I = 192623174.5\,kg$

7) The Moon has a mass of 7.35 x 10^{22} kg and its equatorial radius is 1.74 x 10^6 m. Earth's mass is 5.97 x 10^{24} kg and its equatorial radius is 6.38 x 10^6 m. Calculate the magnitude of the gravitational force exerted by

i) the Moon on a 100-kg astronaut standing on the Moon's surface (162 N)

$m_m = 7.35\times10^{22}\,kg$
$m_a = 100\,kg$
$d = 1.74\times10^6\,m$

$\vec{F}_g = \dfrac{G m_m m_a}{d^2}$

$\vec{F}_g = \dfrac{6.67\times10^{-11}(7.35\times10^{22}\,kg)(100\,kg)}{(1.74\times10^6\,m)^2}$

$\vec{F}_g \approx 162\,N$

ii) Earth on a 100-kg astronaut standing on Earth's surface (978 N)

$m_a = 100 kg$

$m_e = 5.97 \times 10^{24} kg$

$d = 6.38 \times 10^{6} m$

$\vec{F_g} = ?$

$$\vec{F_g} = \frac{G m_e m_a}{d^2}$$

$$\vec{F_g} = \frac{6.67 \times 10^{-11} (5.97 \times 10^{24} kg)(100 kg)}{(6.38 \times 10^{6} m)^2}$$

$$\boxed{F_g \simeq 978 N}$$

iii) Explain why the values of *Fg* in part (i) are different from (ii).

- the Earth is much more massive than the moon

8) Suppose the equatorial radius of Earth was the same as the Moon, but Earth's mass remained the same. The Moon has an equatorial radius of 1.74×10^6 m. Earth's mass is 5.97×10^{24} kg and its equatorial radius is 6.38×10^6 m.

i) Calculate the gravitational force that this hypothetical Earth would exert on a 1.00-kg object at its surface. (132 N)

$\vec{F_g} = ?$

$m_e = 5.97 \times 10^{24} kg$

$d = 1.74 \times 10^{6} m$

$m_o = 1.00 kg$

$$\vec{F_g} = \frac{G m_o m_e}{d^2}$$

$$\vec{F_g} = \frac{6.67 \times 10^{-11} (1.00 kg)(5.97 \times 10^{24} kg)}{(1.74 \times 10^{6} m)^2}$$

$$\boxed{\vec{F_g} \simeq 132 N}$$

ii) How does the answer in part (a) compare to the actual gravitational force exerted by Earth on this object? (9.78N; 13.4 times greater)

$$\vec{F_g} = \frac{6.67 \times 10^{-11} (1.00 kg)(5.97 \times 10^{24} kg)}{(6.38 \times 10^{6} m)^2}$$

$$\vec{F_g} \simeq 9.78 N$$

Compare

$$\frac{i}{ii} = \frac{132 N}{9.78 N} \simeq 13.5$$

(i) is about 13.5 times greater.